Aug. 20, 1957 E. S. RITTNER ET AL 2,803,779

ELECTRON SWITCHING DEVICE

Original Filed April 20, 1950 2 Sheets-Sheet 1

Fig. 1.

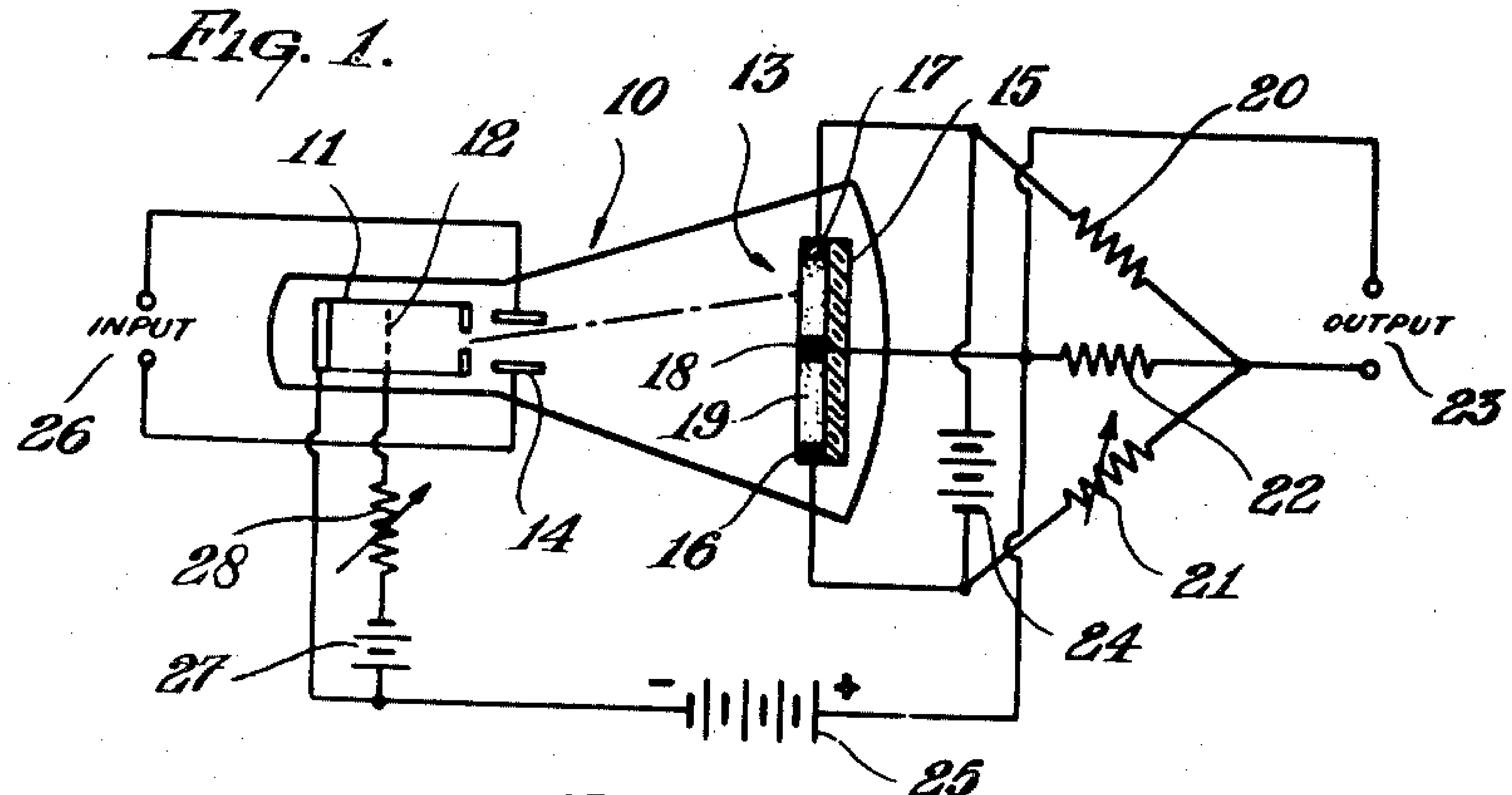

Fig. 3.

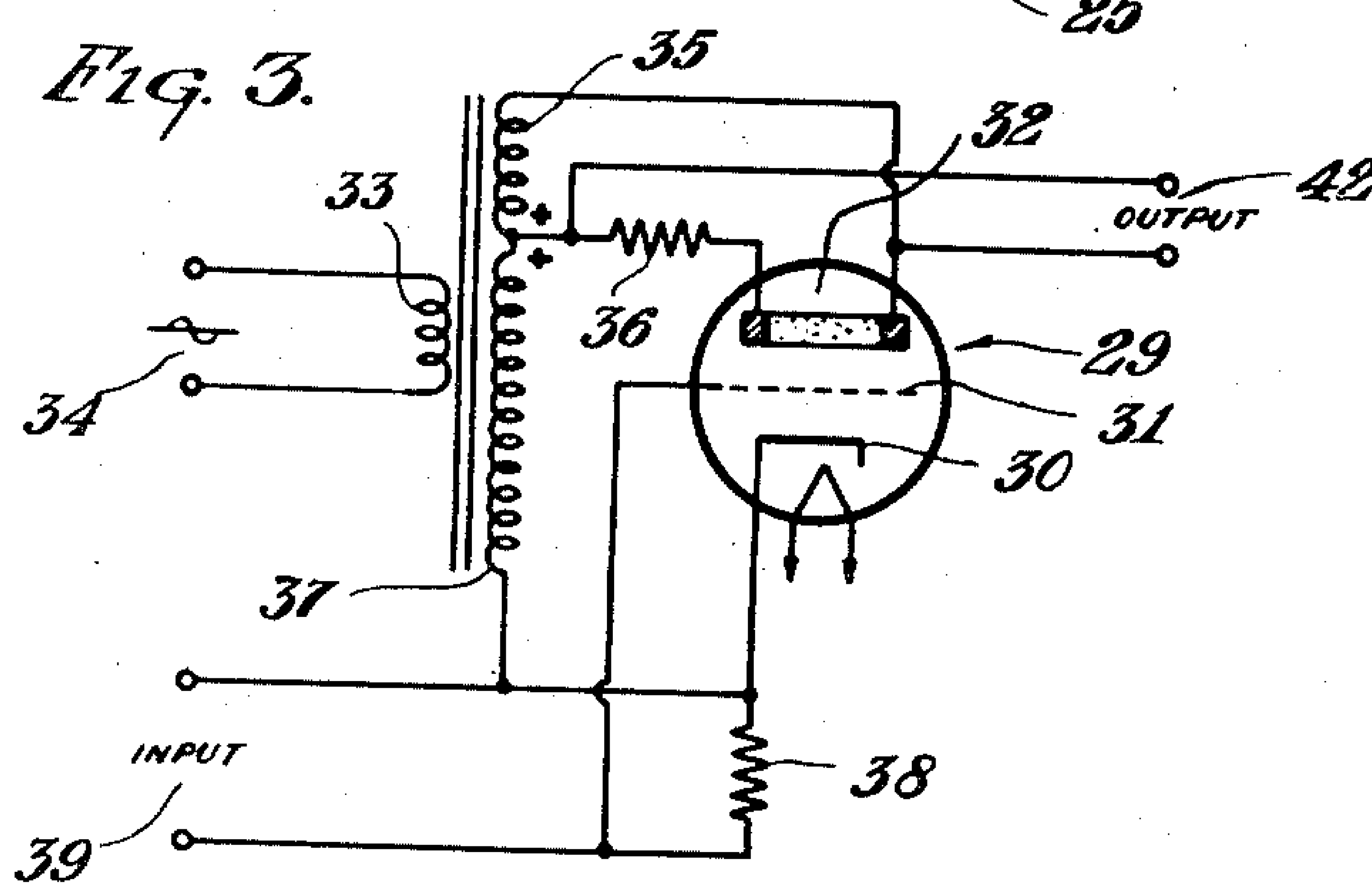

Fig. 2.

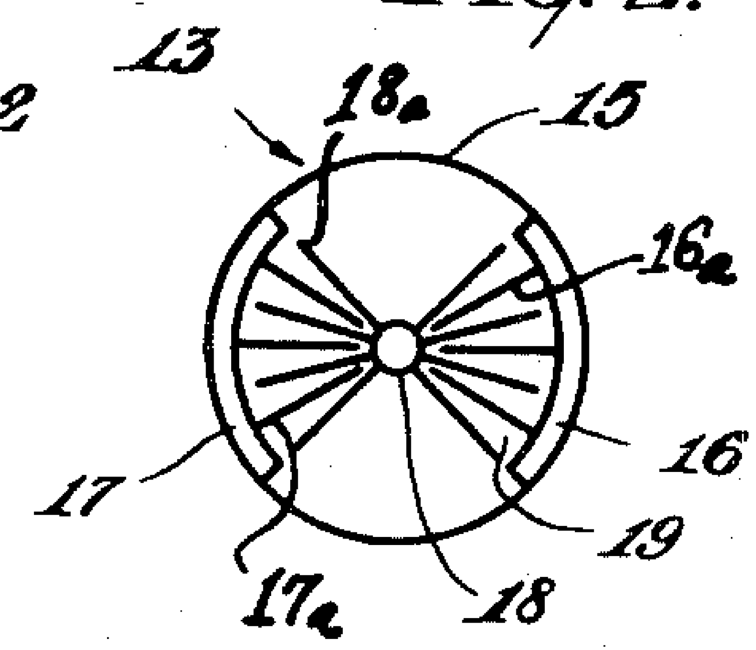

Fig. 4.

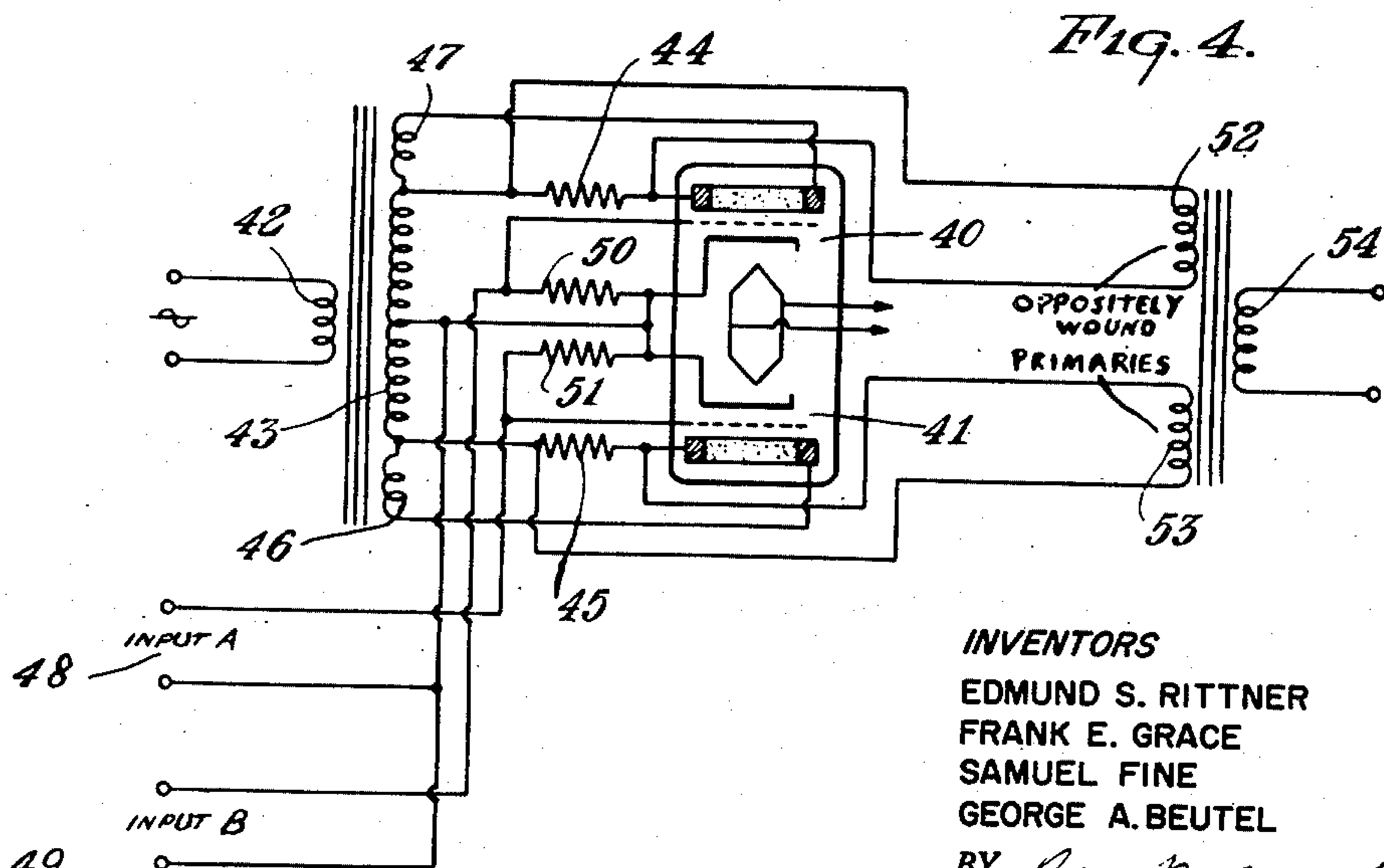

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Fig. 5.

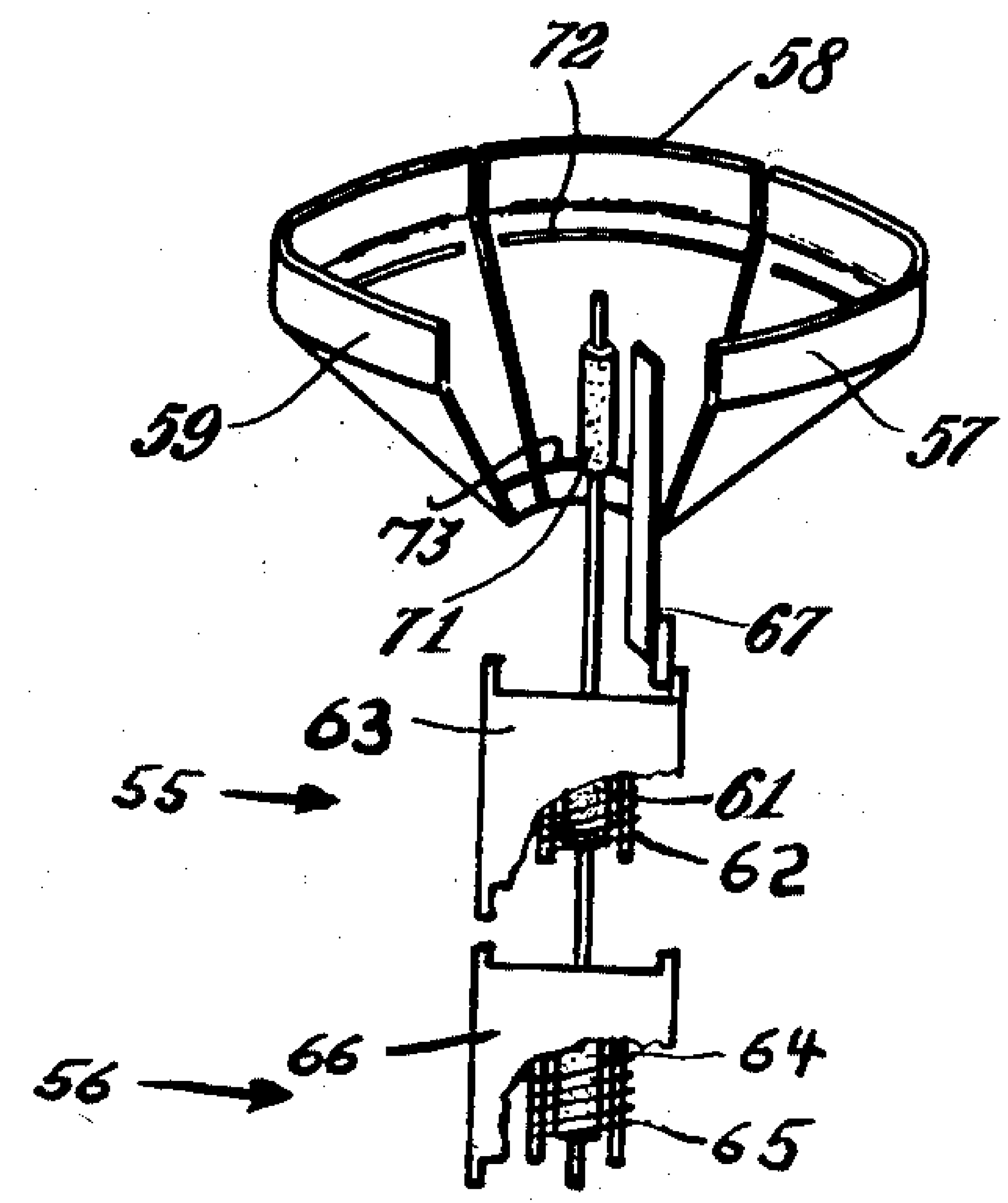


Fig. 6.

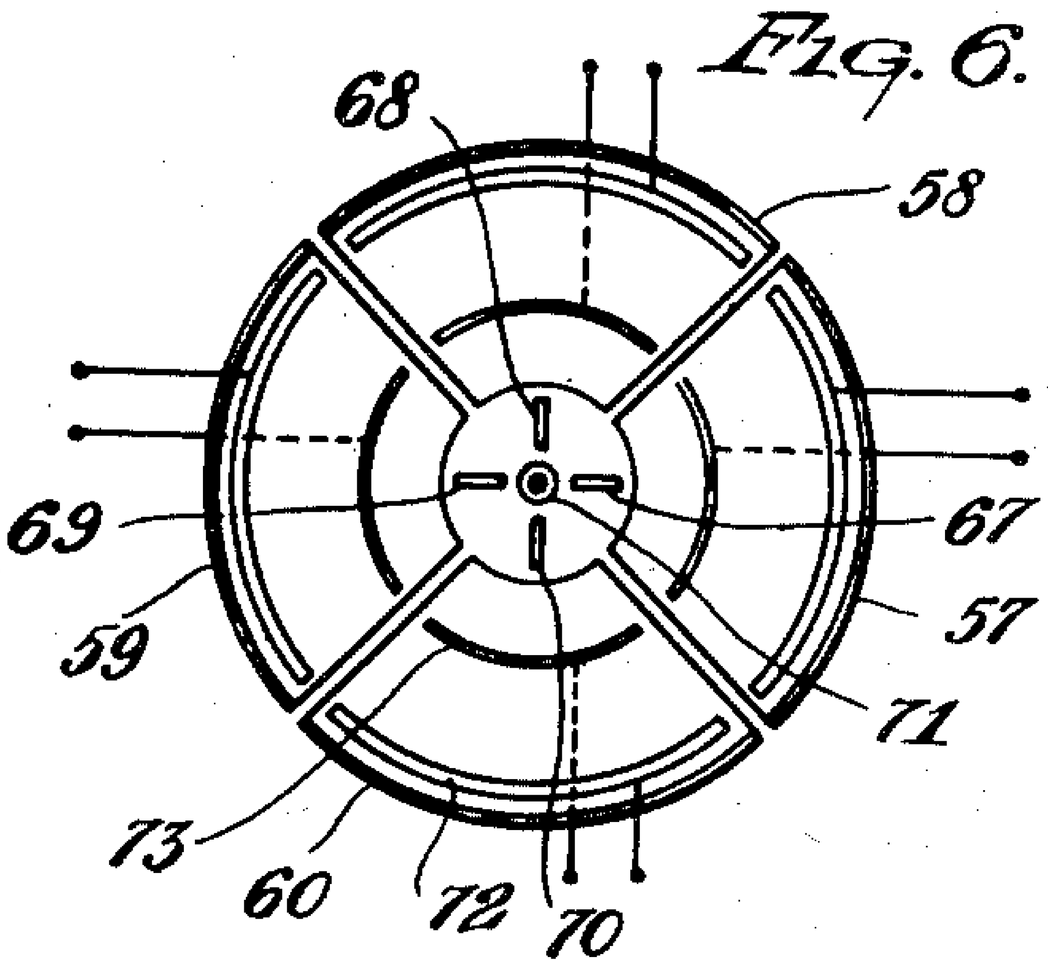


Fig. 7.

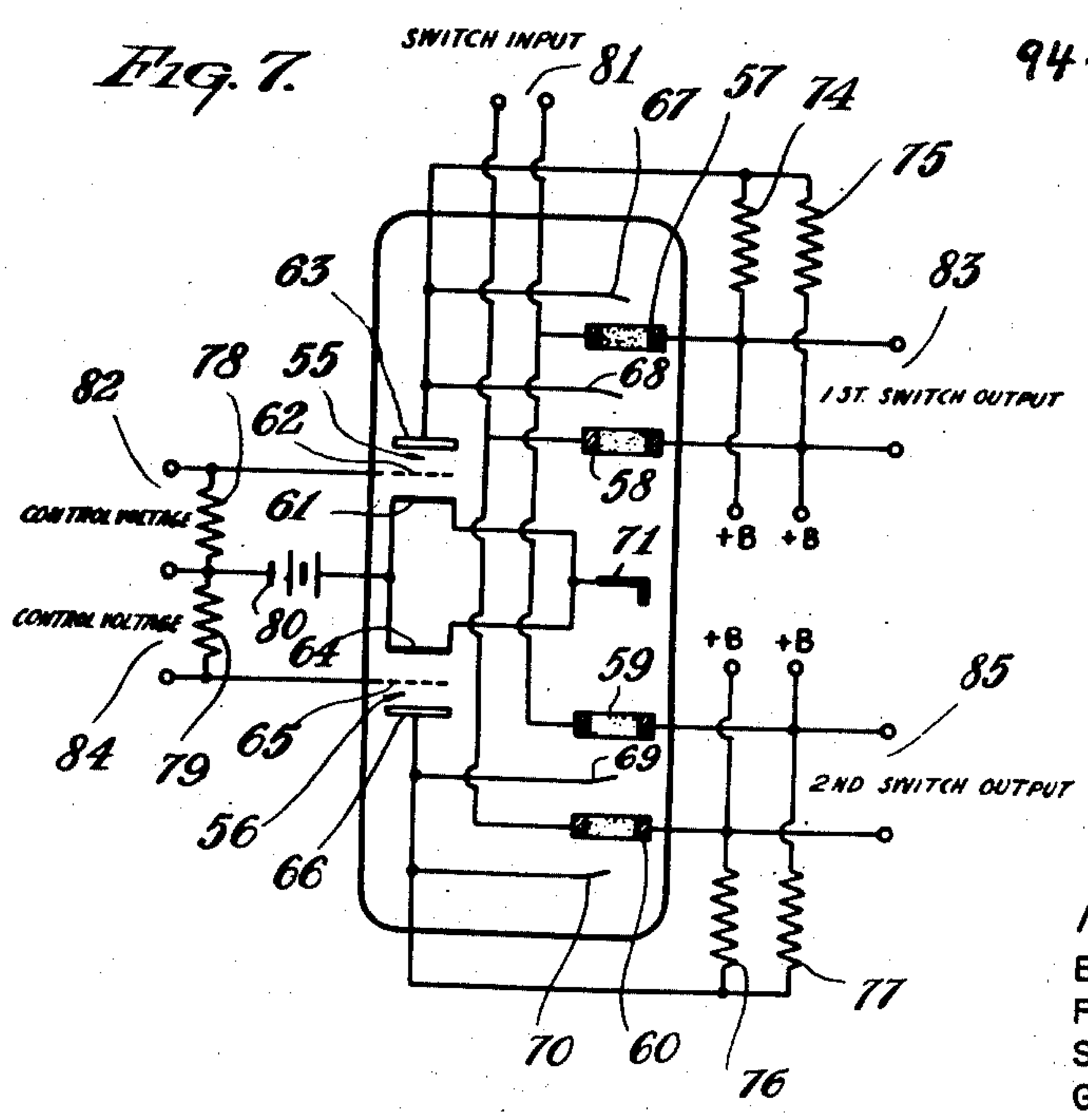
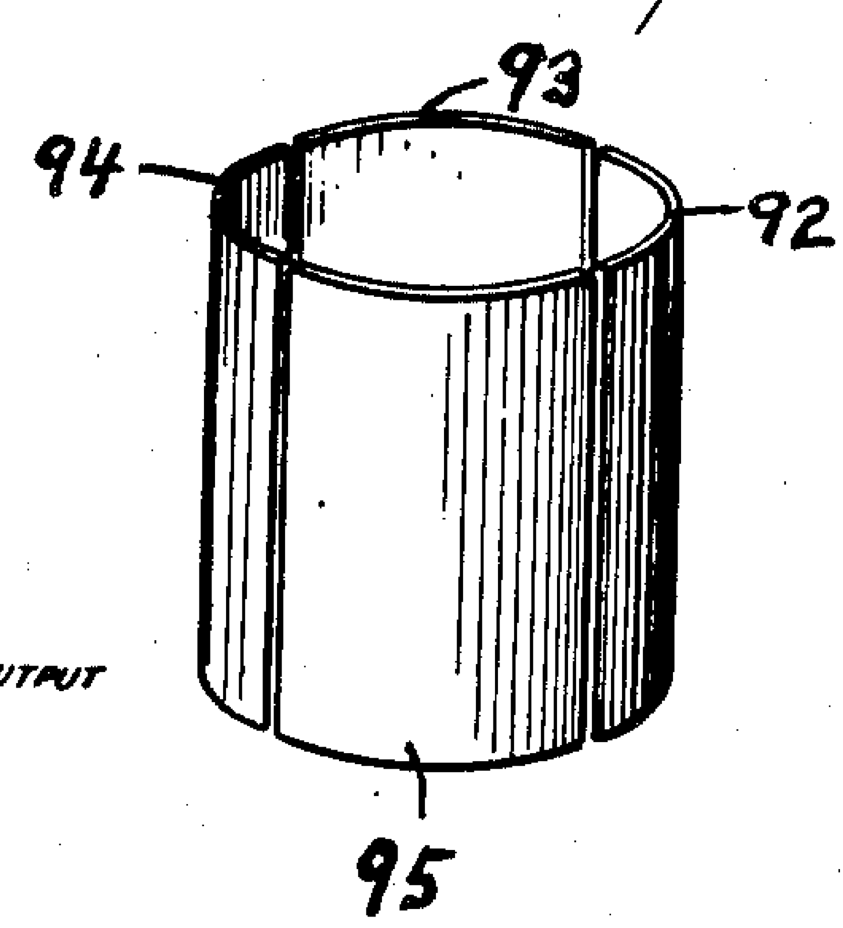


Fig. 8.



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ELECTRON SWITCHING DEVICE

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Original application April 20, 1950, Serial No. 156,972, now Patent No. 2,588,292, dated March 4, 1952. Divided and this application February 7, 1952, Serial No. 274,482

9 Claims. (Cl. 315—10)

The present invention pertains to improvements in electron devices of the type wherein a stream of electrons is caused to impinge on a target of photoconducting semiconductive material whose internal impedance varies as a function of the stream intensity and velocity, and to improved circuit arrangements incorporating such devices.

In the copending application of E. S. Rittner, filed September 22, 1948 and given Serial No. 17,636, now Patent No. 2,540,490, there is disclosed electron devices in which an electron beam is directed onto a photoconductive semiconductive element preferably constituted either by silicon, germanium, thallous sulfide, or lead sulfide, these substances each exhibiting a resistivity which depends on the beam intensity and velocity. The principal object of the present invention is to provide improved structural arrangements for such devices, as well as new and useful switching circuits embodying said improved devices.

For a complete understanding of the present invention reference is made to the following detailed description thereof to be read in conjunction with the accompanying drawing wherein:

Fig. 1 is a schematic diagram of an electron switching tube circuit in accordance with the invention and in which the photoconducting semiconductive target is illustrated in section.

Fig. 2 is a separate plan view of the target structure.

Fig. 3 is a schematic circuit diagram of an amplifier incorporating an electron device which is energized directly from an alternating-current source.

Fig. 4 is a schematic circuit diagram of a differential amplifier employing a pair of amplifiers of the type disclosed in Fig. 3.

Fig. 5 is a perspective view of the electrodes in another electron device in accordance with the invention.

Fig. 6 is a plan view of the electrode structure shown in Fig. 5,

Fig. 7 is a schematic diagram of a switching system employing a tube of the type disclosed in Figs. 5 and 6, and

Fig. 8 is a perspective view of a modified target structure for a tube of the type disclosed in Fig. 5.

Referring now to Figure 1, there is shown a voltage-responsive switching system including an electron device 10 in accordance with the invention provided with a cathode-ray gun structure 11 possessing an intensity-control electrode 12, the cathode-ray beam projected by said gun impinging on a target structure or switching device 13 and being deflectable by a pair of electrostatic deflecting plates 14. As shown in Figs. 1 and 2, the target structure or switching device 13 is formed by a disc-shaped base member 15 of dielectric material along whose circular edge is mounted a pair of arcuately shaped electrodes or contacts 16 and 17 each having a plurality of conductive spokes 16*a* and 17*a* attached thereto. A hub electrode or contact 18 is affixed centrally to said base and provided with radial spokes 18*a* disposed in intermeshing relationship with respect to spokes 16*a* and 17*a*. Coated on the surface of said base in the interstices of spokes 16*a*, 17*a* and 18*a* is a wafer-shaped layer 19 of semiconductive material preferably constituted either by germanium, thallous sulfide, silicon or lead sulfide.

The semiconductive path lying between the spokes on arcuate electrode 17 and hub electrode 18 acts as one arm, and the path lying between the spokes on arcuate electrode 16 and hub electrode 18 acts as a second arm in a Wheatstone bridge circuit whose remaining arms are formed by the external resistors 20 and 21, the latter resistor being variable to effect balancing.

Connected between hub electrode 18 and the junction of resistors 20 and 21, which electrode and junction represent the output diagonals of the bridge, is an output resistor 22 whose ends are also connected to output terminals 23. Connected between arcuate electrodes 16 and 17 at the input diagonals of the bridge is a direct voltage source 24. Connected between the cathode of the electron gun 11 and the hub electrode of target 13 is a source of accelerating voltage 25. The control voltage for activating the switching system is applied to the input terminals 26 connected to deflecting plates 14. A bias voltage from a source 27 is applied to intensity control electrode 12 through variable resistor 28.

The behavior of the switching system is a follows: In the absence of a control voltage across the deflecting plates, the beam from gun 11 strikes the hub electrode 18, and thereby avoids contact with the semiconductive substance on the target. Assuming an initial condition of bridge balance, and with zero voltage on the deflecting plates, no voltage is developed across output resistor 22 of the bridge. The introduction of a voltage across deflecting plate 14 deflects the beam from hub electrode onto the semiconductive layer 19 in a direction depending on the polarity of the control voltage. Thus depending on the direction of deflection, either the resistivity of the semiconductive path interposed between electrodes 16 and 18 or the path between electrodes 17 and 18 is altered to unbalance the bridge in one direction or the other. In consequence, the polarity of voltage established across output resistor 22 is contingent on the polarity of the control voltage applied to the deflecting plates.

The output voltage appearing at terminals 23 may be used to effect a desired switching action in various ways. For example it may be impressed on a polarized relay to effect a switching action in a sense depending on the polarity of the control voltage. The extent to which the resistivity of a particular semiconductive path is altered, and hence the sensitivity of the relay, may be controlled by adjusting resistor 28 to obtain a desired beam intensity. It is also to be noted that a modulating signal may be applied to grid 12 whereby the tube acts to amplify the signal and then by its switching action directs it into a desired channel.

Referring now to Fig. 3, there is shown a switching system employing an electron device 29 in which the voltage imposed across the target and the beam accelerating voltage is derived, without rectification, from an alternating-current source. Electron device 29 includes an indirectly heated cathode 30, a control grid 31 and a target electrode 32 formed by a semiconductive substance of the type hereinabove described interposed between two end terminals.

A transformer is provided having a primary winding 33, connected at terminals 34 to an alternating-current line, a secondary winding 35 connected through an output resistor 36 across the end terminals of target 32, and a tertiary winding 37 arranged in phase opposition to winding 35 and connected between one terminal of target

32 and cathode 30. A grid leak resistor 38 is connected between grid 31 and cathode 30, a pair of input terminals 39 being connected across resistor 38, and a pair of output terminals 42 being connected across resistor 36.

In operation, a pulsating direct-current component will appear across resistor 36 whose amplitude will depend on the magnitude of the control voltage impressed on the grid 31. The voltage established across resistor 36 may be used to actuate a relay, and due to the increased amplification afforded by the electron device, the system is responsive to input control signals of small amplitude. Thus a highly sensitive control device is provided entailing a minimum number of components.

Referring now to Fig. 4, there is disclosed a differential amplifier employing a pair of electron devices of the type disclosed in Fig. 3, preferably enclosed in a single envelope, whose combined output depends on the relative values of the applied input voltage. As in Fig. 3, the voltages imposed across the targets of the tubes 40 and 41 and the beam accelerating voltages are derived without rectification through a transformer whose primary 42 is connected to an alternating current source. The transformer is provided with a centertapped secondary winding 43 whose ends are connected through resistors 44 and 45 to one terminal of the targets of tubes 40 and 41 respectively, and whose centertap is connected to the interconnected cathodes of said tubes. Auxiliary secondary windings 46 and 47 are provided, one end of each auxiliary secondary being connected to a respective end of said secondary 43, the other end of each auxiliary secondary being connected to the other terminal of a respective target.

The input voltages A and B are applied at terminals 48 and 49 which are connected respectively across grid resistors 50 and 51 connected between the grid and cathodes of tubes 40 and 41. The voltage developed across resistor 44 is applied to one primary 52 of an output transformer, and the voltage developed across resistor 45 is applied to an opposingly wound primary 53 of the transformer. In consequence the average voltage developed in the secondary 54 represents the differential resultant of the primary voltages. In operation, since the accelerating voltages applied to the targets of tubes 40 and 41 are 180 degrees out of phase, the tubes operate alternately, the voltages developed across resistors 44 and 45 depending on the relative amplitudes of the input voltages A and B respectively. It is to be noted that in the control systems disclosed in Figs. 1, 3 and 4, the input circuits are independent of the output circuit and no interaction therebetween can occur.

Another embodiment of an electron device in shown in Figs. 5, 6 and 7, the device comprising in a single envelope, a pair of high-mu triodes 55 and 56 and a cone-shaped target constituted by four electrically separated sections 57, 58, 59 and 60. Triode 55 is constituted by a cathode 61, a grid 62 and an anode 63, and triode 56 by a cathode 64, a grid 65 and an anode 66. Connected directly to the anode 63 are a pair of blade-like control electrodes 67 and 68, electrode 67 being associated with target section 57 and electrode 68 with section 58. Similarly, connected directly to anode 66 is a pair of blade-like control electrodes 69 and 70, electrode 69 being associated with target section 59, and electrode 70 with section 60. In Fig. 5, only electrode 67 is shown, the others being omitted for purposes of clarity. The target is irradiated by an electron beam emitted from a cylindrical cathode 71, triode cathodes 61 and 64 being mounted on a common support therewith.

Each section of the target is formed of non-conductive material and is provided with a pair of spaced arcuate terminals or contacts 72 and 73, the surface between the two terminals being coated with a semiconductive photoconductive substance of the type described for layer 19 of Fig. 1. The anode 63 is connected to one terminal of target section 57 through a high resistance 74, said one terminal being connected to the positive pole of a high-voltage source. The anode 63 is also connected to one terminal of target section 58 through a high resistance 75, said one terminal being connected to the positive pole of a high-voltage source.

Anode 66 is connected to one terminal of target section 60 through a high resistance 76, a high positive voltage being applied at this point. The anode 66 is also connected to one terminal of target section 59 through a high resistance 77, said one terminal being connected to the positive pole of a high-voltage source. Grid 62 is connected to cathode 61 through a grid resistance 78 and a bias battery 80, grid 65 being connected to cathode 64 through a grid resistance 79 and the same bias battery.

Considering section 57 separately, in operation, with zero control potential on the grid 62 of tube 55, electrons from the cathode 71 strike the entire surface of section 57 except for a sector in the region of blade electrode 67, which being at a lower potential than the target section because of the voltage drop across resistance 74 acts as a shield. When however, a negative control potential is applied to grid 62, the anode current is reduced with a resultant decrease in the voltage drop across resistances 74 and 75, thereby reducing the sector of the target section 57 which is not irradiated. This action, it will be realized, is similar to that which obtains in the conventional tuning indicator tube. Thus as the shielded sector on the target section varies with the control voltage applied to grid 62, the internal resistance of the target section is accordingly altered. Blade 68 has the same control influence on section 58. The same effect is experienced with respect to the influence of a control voltage on grid 65 on the internal resistance of sections 59 and 60.

This effect may be used for example to provide a double pole double throw switching action by applying the signal to be switched to terminals 81, one of which is connected to one arcuate terminal of both sections 57 and 59, and the other of which is connected to one arcuate terminal of sections 58 and 60. The other arcuate terminals of sections 57 and 58 are connected to one pair of output terminals 83 while the other arcuate terminals of sections 59 and 60 are connected to output terminals 85.

By applying a negative control voltage to terminals 82 connected to grid 62, the signal to be switched is fed to output terminals 83 and by applying a negative control voltage to terminals 84 connected to grid 65, the signal to be switched is fed to output terminal 85. While there has been shown a target arrangement employing four sections, it is obvious that a greater number may be used in conjunction with blade electrodes coupled to the anodes of amplifier tubes to effect more complex switching functions.

By using a conically-shaped target the formation of a sensitive layer on the inner surface thereof is greatly facilitated. This is accomplished by inverting the cone and applying the material by vacuum evaporation. Preferably the cathode is protected by a small cap (not shown) attached to the end of the support. The conical target structure shown in Fig. 5 may be replaced by one of tubular shape and having four sections 92, 93, 94, and 95, as illustrated in Fig. 8 or by other shapes if desired. While the terminals 72 and 73 in Fig. 5 are shown in circumferential positions, it is to be understood that radially disposed terminals may alternatively be employed, in which case should the sensitive area intermediate the terminals not be irradiated then the resistance therebetween would effectively constitute an open circuit. Similarly in the target shown in Fig. 8, the terminals may be arranged either longitudinally or circumferentially. It is also to be noted that several targets may be contained in a common envelope.

This application is a division of a copending application Serial No. 156,972, filed April 20, 1950, now Patent No. 2,588,292.

While there have been shown what at present are considered preferred embodiments of the invention, it will be evident that many changes and modifications may be made therein without departing from the essence of the invention, and it is intended in the anexed claims to cover all such changes and modifications as fall within the scope and true spirit of the invention.

What is claimed is:

1. In an electron device, a switching system comprising a cathode, a target electrode surrounding said cathode and formed by a plurality of discrete sections each including a pair of spaced terminals and an active element connected therebetween constituted by a photoconductive semiconductor, and a like plurality of deflecting blades each interposed between a respective section and said cathode.

2. In an electron device, a switching system comprising a cathode, a conical target electrode surrounding said cathode and formed by a plurality of discrete sections each including a pair of spaced terminals and an active element connected therebetween constituted by germanium, and a like plurality of deflecting blades each interposed between a respective section and said cathode.

3. In an electron device, a switching system comprising a cathode, a cylindrical target electrode surrounding said cathode and formed by a plurality of discrete sections each including a pair of spaced terminals and an active element connected therebetween constituted by thallous sulfide, and a like plurality of deflecting blades each interposed between a respective section and said cathode.

4. In an electron device, a switching system comprising a cathode, a target electrode surrounding said cathode and formed by four discrete sections each including a pair of spaced terminals and an active element connected therebetween and constituted by a photoconductive semiconductor, four deflecting blades each interposed between respective sections and said cathode, and a pair of amplifying systems each including a cathode, a grid and an anode, the anode in one amplifying system being connected to two of said blades, the anode in the other system being connected to the remaining two blades.

5. In combination, a plurality of switching circuits, each of said circuits having a switching device therein, each of

said switching devices comprising a wafer-shaped photoconductive semiconductive body and contacts connected to said body, means to apply a potential to said contacts, an output circuit associated with each of said switching circuits, and means to selectively project an electron beam upon any one of said bodies.

6. A combination in accordance with claim 5 wherein said body is of germanium material.

7. In combination, a plurality of switching circuits, each of said circuits having a switching device therein, each of said switching devices comprising a wafer-shaped, photoconductive, semiconductive body and contacts connected to said body, means to apply a potential to said contacts, an output circuit associated with each of said switching circuits, means to project electrons upon said semiconductive bodies, and means to actuate selectively said switching circuits including means to control the electron current incident on the semiconductive bodies.

8. A switching device comprising electron-beam producing means, at least two target electrode elements positioned to be impacted by said electron beam, each of said target electrodes comprising a pair of spaced terminals and a photoconductive semi-conductor connected to said terminals, means for applying a potential across the terminals of said electrodes, output circuits coupled to said terminals and thus to each of said target electrodes, and means for controlling the electron-beam current incident on the target electrodes thereby selectively inducing signals in the output circuits.

9. A switching device as set forth in claim 8 wherein the semi-conductor is selected from the group consisting of silicon and germanium.

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